VDI Arbeitskreis Landtechnik Köln
Programm WS 2012/13

Dienstag 19. Maerz 2013, 17:30 Uhr

„Globale Perspektiven in der Nutzung von Bio-Energie“.

I. Weltweiter Überblick unterschiedlicher energiebezogener Agrarprojekte

Prof. (em.) Dr. Marc Janssens, Universität Bonn, INRES-Tropical crops

I. AGRICULTURE IS AN ALTERNATING PROCESS OF CONCENTRATION VS./DILUTION OF RESOURCES

Sugar beet fertigation

Morocco

Multilayer oasis agriculture

Bush fire

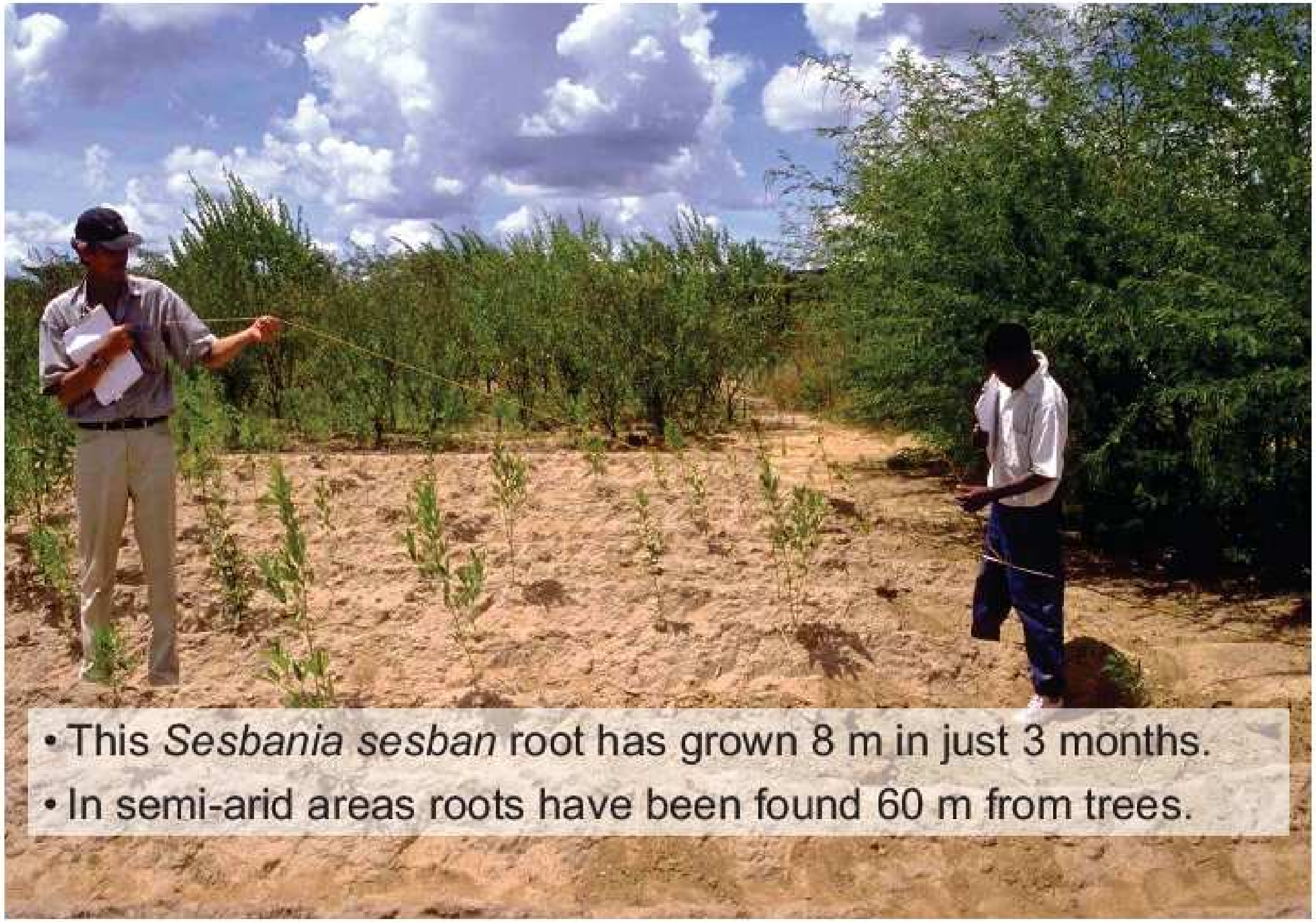
Benin

Peuhl cattle

Each agricultural system is a human attempt to secure a sustainable food supply in a given environment

Janssens et al. In: Speth et al. 2010

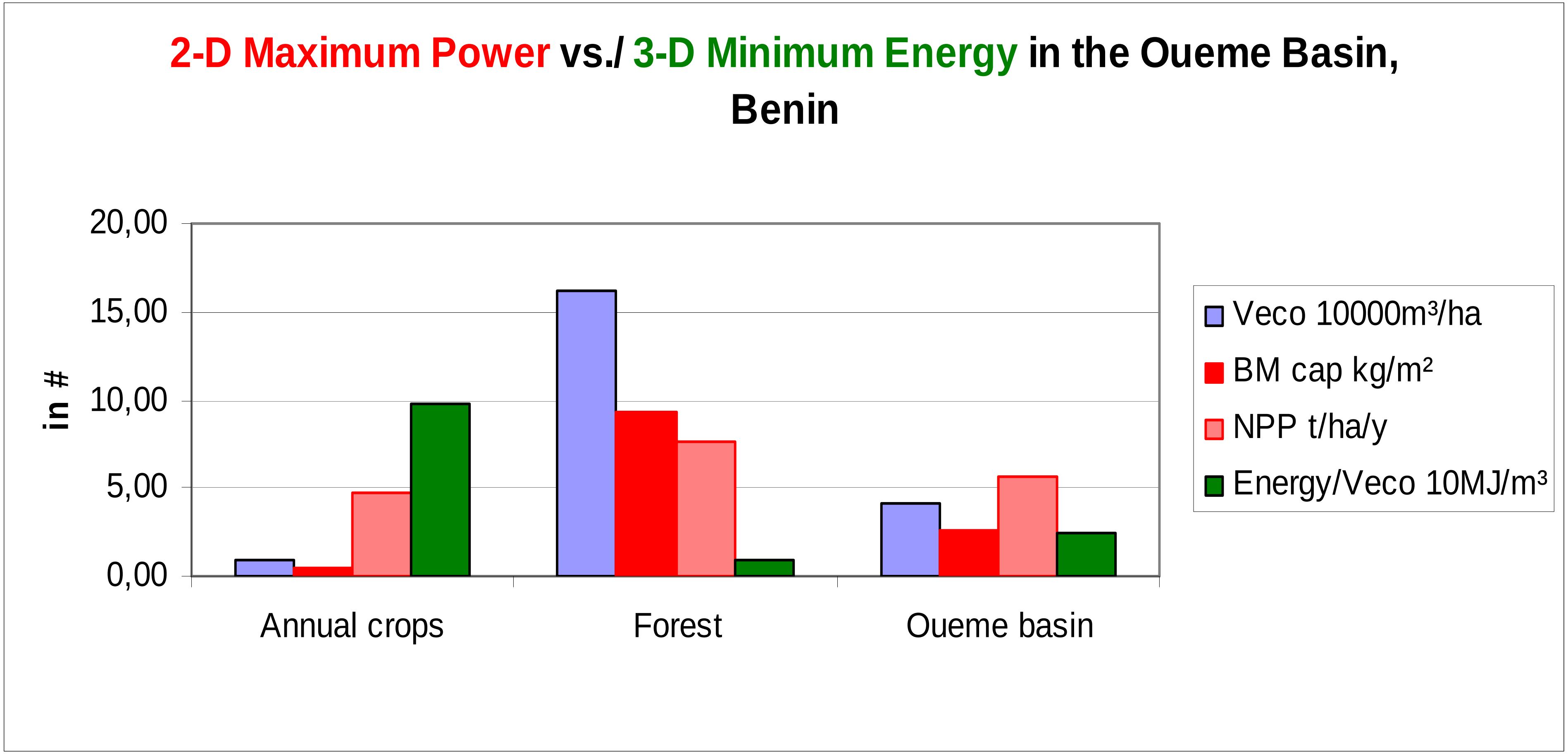
II. CROPS ARE NOT WEIGHT WATCHERS BUT SPACE INVADERS



Root growth

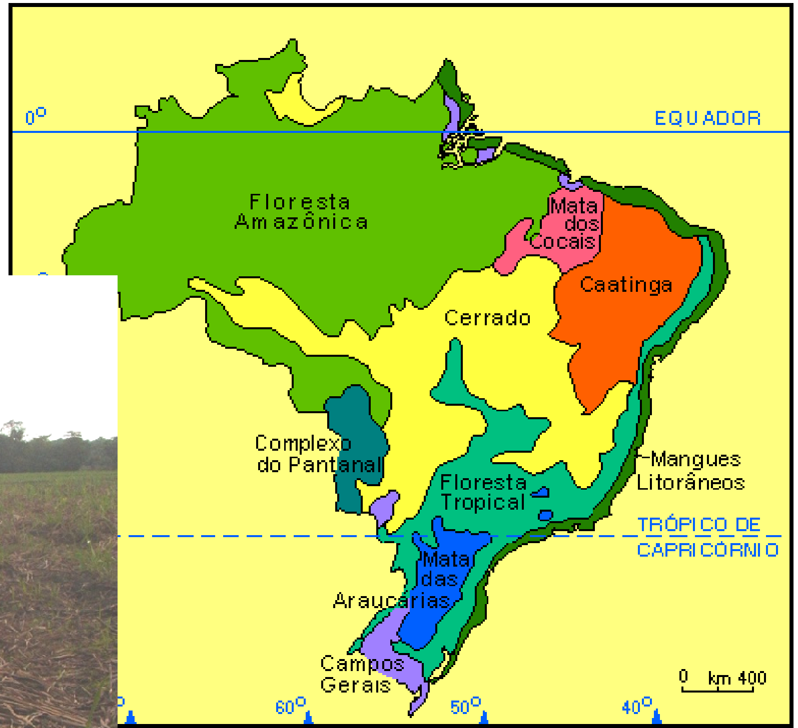
Source: ICRAF, Nairobi, Kenya

III. CROPS ARE MAXIMIZING ENERGY/M² BUT MINIMIZING IT PER M³



JANSSENS, M.J.J., POHLAN, J., KEUTGEN, N. & TORRICO, J.C., 2009. Plants are not weight watchers but space invaders.
In: Technology, Resource Management & Development Volume No. 6 – Special issue in Honour of Prof. Dr. Hartmut Gaese.
Technology and Resource Management in the Tropics and Subtropics – State of the Art and Future Prospects.
Fachhochschule Köln, Institute for technology and Resources in the tropics and Subtropics, Cologne, Germany. Pp.115-122

IV. BRAZILIAN SUGAR CANE AT THE FORE OF THE BIOETHANOL REVOLUTION



SUGAR CANE: Estimates of eco-volume and bio-volume

(Mexico, Chiapas, Huixtla; average of 6 years; *source: Pohlan et al. 2005*)

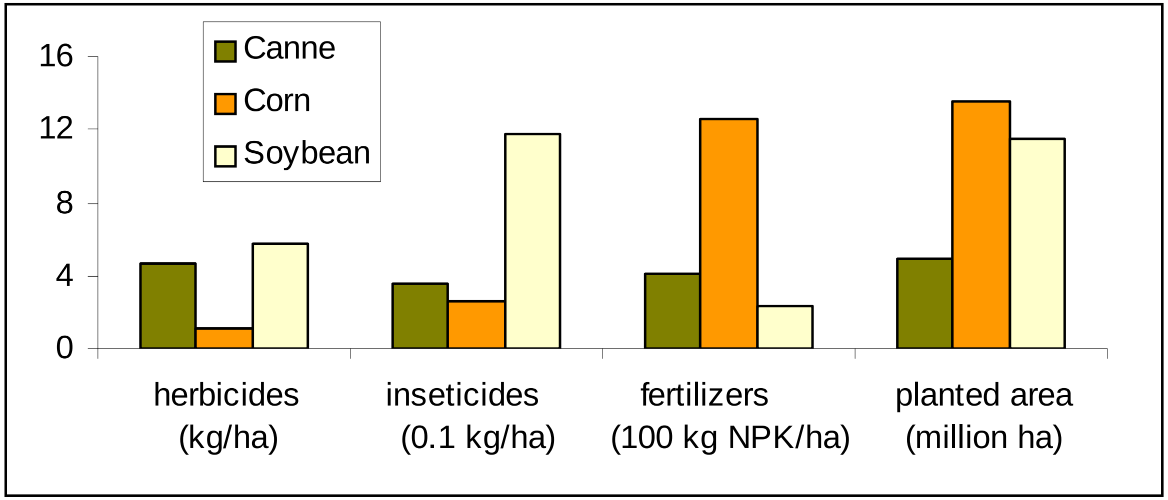
	Yield (fresh matter in t/ha/year)			Biometrical characteristics of sugar cane stand					
	Cane	Cane tops	Total	Eco-height (d)	Basal Area (BA) m^2/ha	Eco-volume (V_{eco}) m^3/ha	Bio-volume (BA * d) m^3/ha	Wesenberg (wb) = (V_{eco}/V_{bio})	Crowding intensity Ci = 100/wb (%)
Green cane	125	18.7	143.7	2.46	131.0	24600	322.3	76.3	1.3
Burn 1x	96	14.4	110.4	2.09	97.5	20900	203.8	102.6	1.0
Burn 2x	89	13.3	102.3	1.97	72.3	19700	142.4	138.3	0.7
	Dry matter yield (t/ha/year)			Energy content					
	Cane	Cane tops	Total	MJ/ kg dry matter	Yield (GJ/ha) Output	Yield (GJ/ha) Loss	MJ/ m^3 Eco-volume	MJ/ m^3 Bio-volume	Gross photosynthesis (t/ha/year)
Green cane	41.7	6.3	48.0	18.0	864	0	35.1	2681	192
Burn 1x	32.0	4.8	36.8	18.0	662.4	201.6	31.7	3250	147.2
Burn 2x	29.7	4.5	34.2	18.0	615.6	248.4	31.2	4323	136.8
					Maximum power law			**Agri-cultural concen-tration**	**Bio-industrial concen-tration**
				→Concentration path→					
Site	Atmos-phere					**Eco-volume**	**Bio-volume**		**e.g. Bio-ethanol**
Active ingredient	CO_2 360 ppm					$(CH_2)_n$			C_2H_5OH
Energy status	0 MJ/ m^3					**> 30 MJ/m^3**	**> 2500 MJ/m^3**		**22600 MJ/m^3 (or 1000 l)**

ETHANOL YIELD

PRODUCT	L /t	L/Y/ha
Sugar cane	70	400 – 12000
Maíze	360	250 – 2000
Cassava (root)	180	500 – 4000
Sweet potato	120	1000 – 4500
Wood	160	160 - 4000

Dr. Roberto Best y Brown
CREVER-Universidad Rovira i Virgili
CIE-UNAM, Abril 2005

Agrochemicals demand



Source: Macedo, 2002

Alcohol from sugar cane

- Average productivity (in São Paulo)

    70 t cane/ha at 85 l/t

- Bagasse production (with 50% moisture, per ton of cane)

    250 kg/t cane + 30% surplus i.e. 140 kg as tops & leaves ("barbojo")

A mill processes ca. 1 mio t cane/y and costs ca. US$25 mio

Energy balance in ethanol production

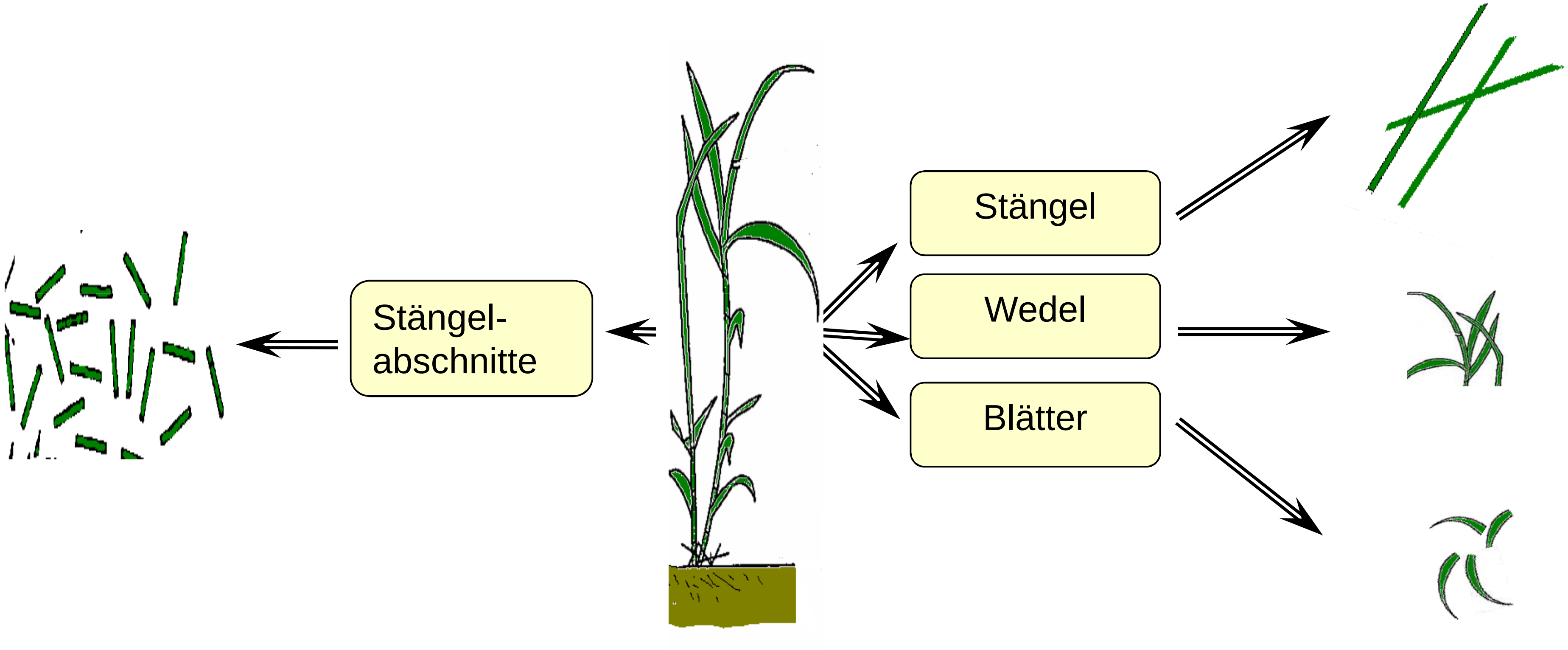
	Average	Best values
Energy demand (MJ/ton canne)		
Agricultural activities	**189.9**	**175.5**
Industrial activities	**46.1**	**36.4**
Energy production (MJ/ton canne)		
Ethanol produced	**1996.4**	**2045.3**
Bagasse surplus	**175.1**	**328.5**
Output/Input	**9.2**	**11.2**

Source: Macedo, 2002

• ZUCKERROHRERNTE

HEUTE und **ZUKÜNFTIG**

Ein Produktions**ziel** : **Drei** Produktions**ziele:**



Konventionelle
Erntemaschinen

Neuartige Lösungen
Zum Beispiel:
“Kölner Lösung“

Quelle: Carl-Freidrich Gaese et al.

Die Nutzpflanze Zuckerrohr

Quelle: Carl-Friedrich Gaese et al.

Verhältnis zwischen Stängel- und Restmasse ~ 1:1

Flächenproduktivität von 90 t Zuckerrohrstängel / ha

Wedelverbund mit grünen Blättern	17 t/ha -> 10%	Ober-irdisch: 152 t/ha Bio-masse	**183 t/ha = 100 %**
Verbund von Stängeln und trockenen Blättern	90 t/ha -> 50 % 45 t/ha -> 25 %		
Wurzelwerk des gesamten Stockes	31 t/ha -> 15 %		

- Der Integrale Mobile Prüfstand (IMP) im Zuckerrohrfeld

Mit Dank an Frau Prof. Dagmar Gaese, Carl-Friedrich Gaese, Torsten Meyer & Ehrhard Schilling

V. ENERGY CONCENTRATION OF PLANT COMPONENTS

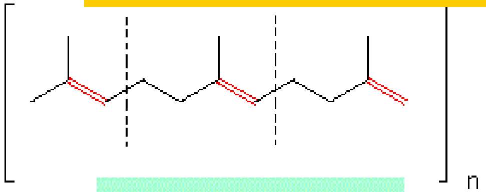
Table: Energy content & biosynthesis costs (in g glucose) of plant components

Component	Energy content (kJ / g)	g glucose / g product	Transport g glucose / g product	Minimum energy costs (kJ/g product)
Lipid	38.9	3.030	0.159	49.4
Lignin	26.4	2.119	0.112	34.6
Protein -Glycine (AA)	23.0 8.7	1.824	0.096	29.8
Organic acids -Oxalic acid -Malic acid -Pyruvic acid	 2.9 10.0 13.2	0.906	0.048	14.8
Further carbohydrates -Terpens -Polyglucan -Glucose	 46.9 17.6 15.5	1.211	0.064	19.8

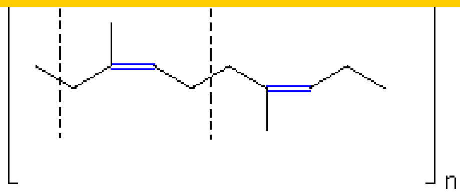
AA = Amino acid

Keutgen November 2007; after Penning-Devries

VI. BIODIESEL THROUGH TRANSESTERIFICATION IS SELF-DEFEATING

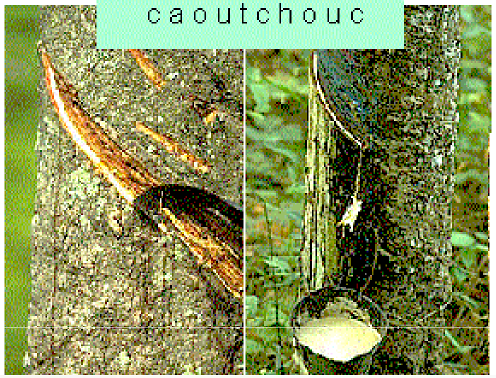


caoutchouc



gutta-percha

Rubber-like Polymers/ Polyisoprenes



Euphorbia tirucalli
(Pencil Euphorb)
(Euphorbiaceae)

Hevea brasiliensis
Euphorbiaceae

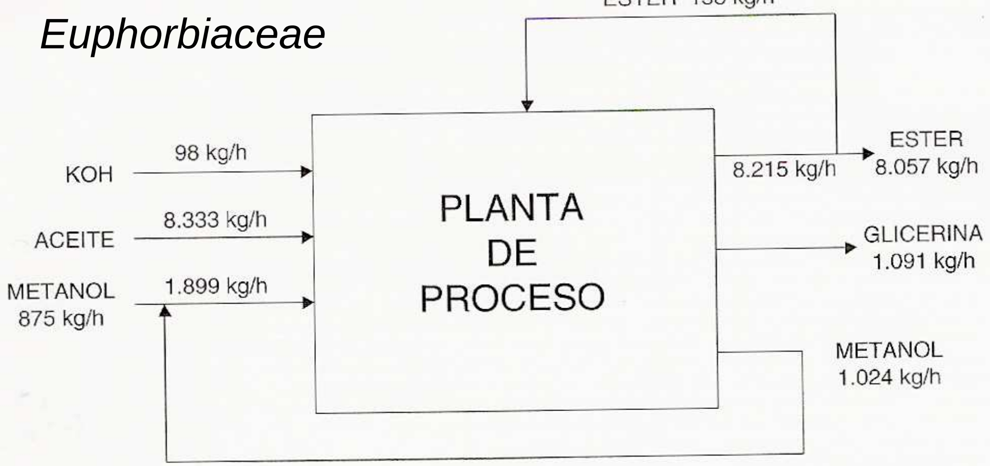


Figura 9.1. Planta de metiléster.

Keutgen
November 2007

RICINUS

(Castor oil -Euphorbiaceae)

Yields 500-5000kg/ha

Parameter	Unit	Minimum	Average	Maximum	Source
Seed yield	Dry tonne/Ha/ year	0.3	0.5	5	
Rainfall requirements	Mm/year	750		1000	[1]
Oil contents of seeds	% of mass	35	45	55	
Oil yield after pressing	% of mass of seed input	30	40	48	
Energy content of oil	MJ/kg		36		[2]

JATROPHA (Euphorbiaceae)**: LUXOR - Tropfenbewässerung mit Stadtabwässern**

Late fruit setting and
Deceiving yields < 1 t seed/ha

JATROPHA
(FAO 2010)

Mali (GTZ project)

TABLE 10: **GROSS MARGINS FROM SMALL-SCALE JATROPHA FARMING, OVER ONE YEAR (TZS/HA)**

	LOW SEED PRICE	MEDIUM SEED PRICE	HIGH SEED PRICE
Costs			
Irrigation	12 250	12 250	12 250
Weeding	24 500	24 500	24 500
Harvesting	343 000	343 000	343 000
Total costs	379 750	379 750	379 750
Revenue			
Harvest (kg/ha)	1 653	1 653	1 653
Price (kg)	100	200	300
Total revenue	165 300	330 600	495 900
Net benefit	-214 450	-49 150	116 150
Gross Margin	**-130%**	**-15%**	**23%**

Adapted from Messemaker (2008).

VII. COMPETITIVE ADVANTAGE OF OIL PALM

Rolf Härdter (2002)

International Potash Institute, c/o K+S KALI GmbH, Bertha-von-Suttner-Str.7, 34131 Kassel, Germany. Fax: +49 561 9301 1416, E-mail: rolf.haerdter@kali-gmbh.com

Thomas Fairhurst

Potash & Phosphate Institute/Potash & Phosphate Institute of Canada – East & Southeast Asia Programs, 126 Watten Estate Road, Singapore 287599. E-mail: tfairhurst@eseap.org

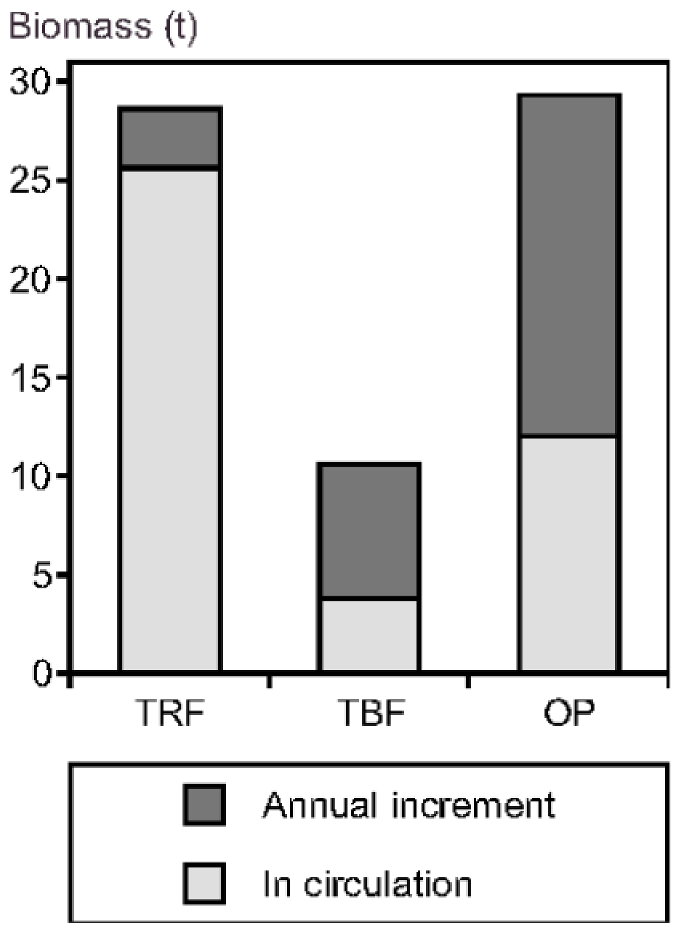


Figure 8. Net annual biomass production for tropical rainforest, temperate beech forest and oil palm (Härdter et al., 1997).

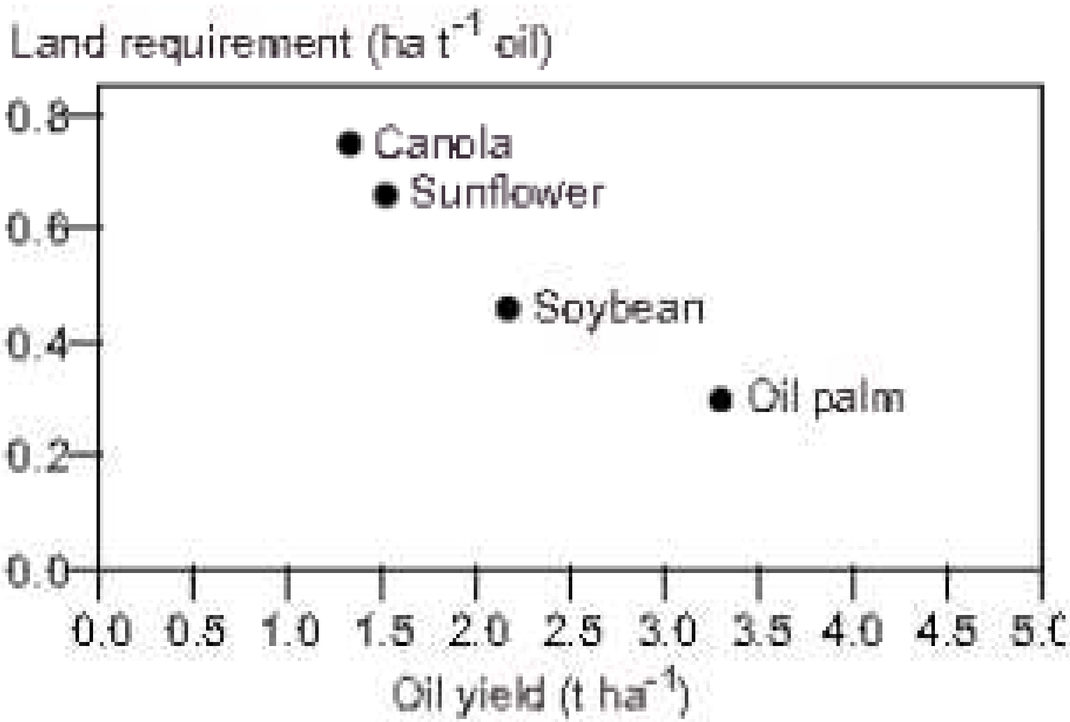


Figure 7. Land area required to produce 1 t oil and oil yields for major vegetable oil crops.

Yield Performance of Planting material Reported by Various Seed Producers in Malaysia

Planting Material	Year Planted	FFB yield (t/ha/yr)	O/B (%)	Oil yield (t/hha/yr)
DxDxCI/UA C/SP	1962	22.6	21.9	4.9
DxDxAVROS	1964	31.0	23.5	7.3
DxDxAVROS	1968	31.1	22.1	6.9
DxDxAVROS	1970	31.6	24.2	7.6
DxDxDY-AVROS	1979	33.3	25.8	8.6
DxDxAVROS	1979	34.5	25.8	8.9
DxDxYangambi	1988	35.1	26.0	9.5
DxDxYangambi	1991	34.8	31.1	10.8
DxDxNigeria	1991	36.1	31.9	11.5

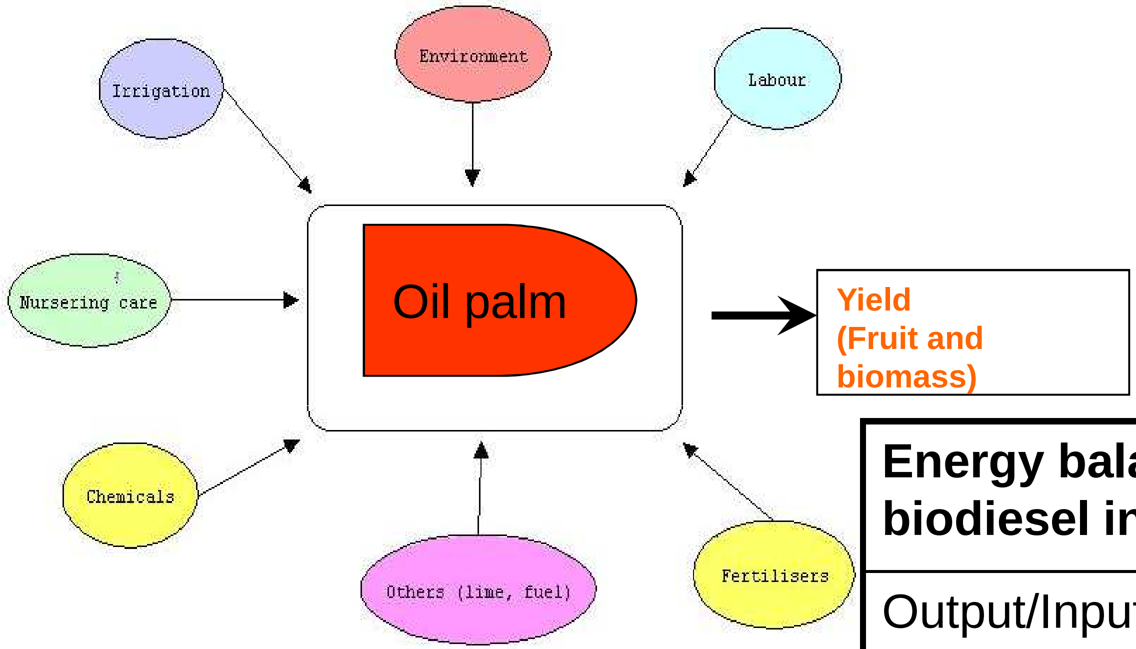
MOHD BASRI WAHID & RAJANAIDU, N

MPOB

MALAYSIAN PALM OIL BOARD
(MPOB)

Flow of energy investment in a oil palm plantation

(cfr. Emergy analysis by ODUM)

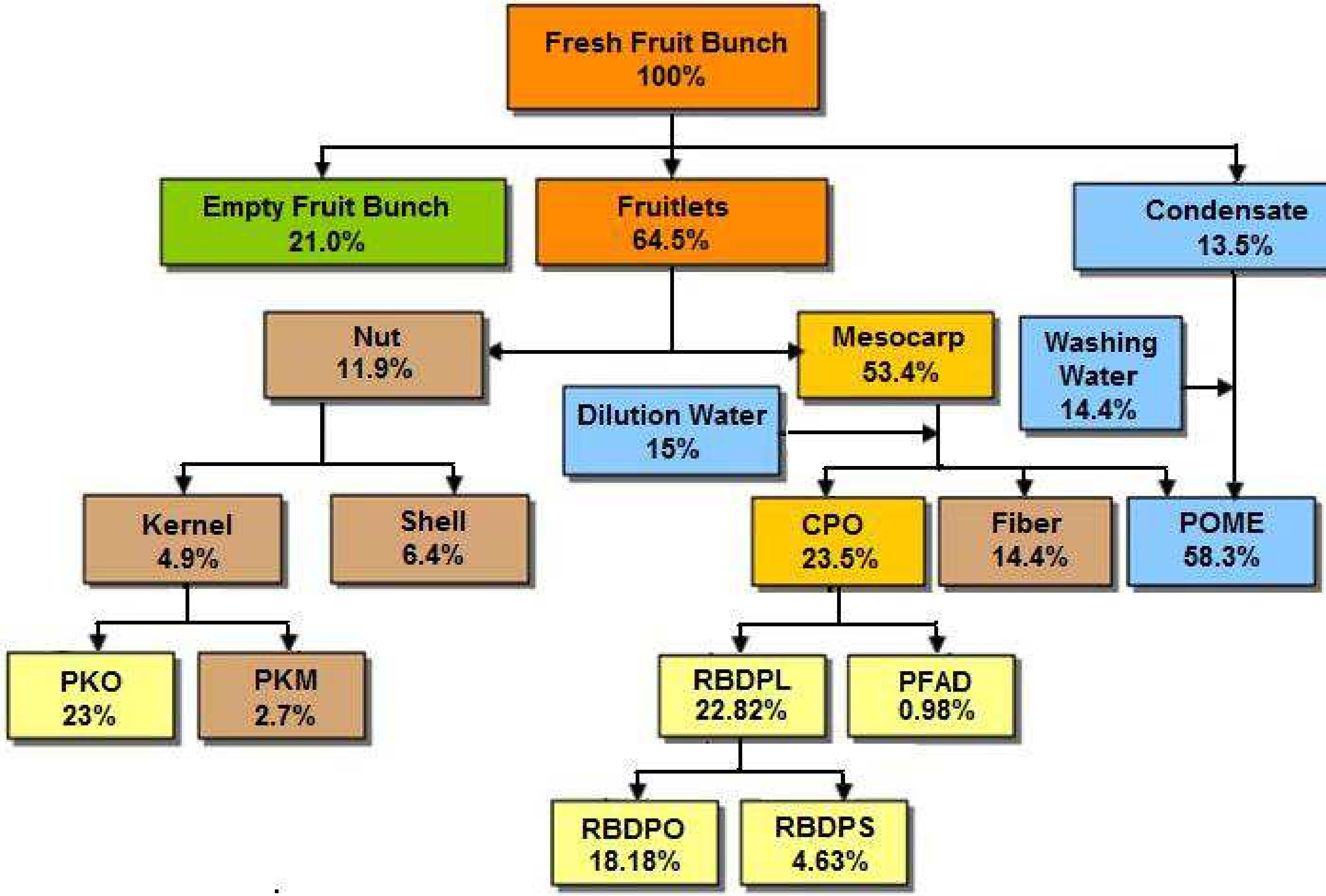


Energy balance of biodiesel production de biodiesel in oil palm (2 x 3 plantations)		
Output/Input→	Brazil	Colombia
A	8.1	6.9
B	13.3	5.9
C	7.8	6.8

Roselis Ester da Costa et al.2006→

OIL PALM PROCESSING & PARTITIONING

Importance of Byproducts!!!



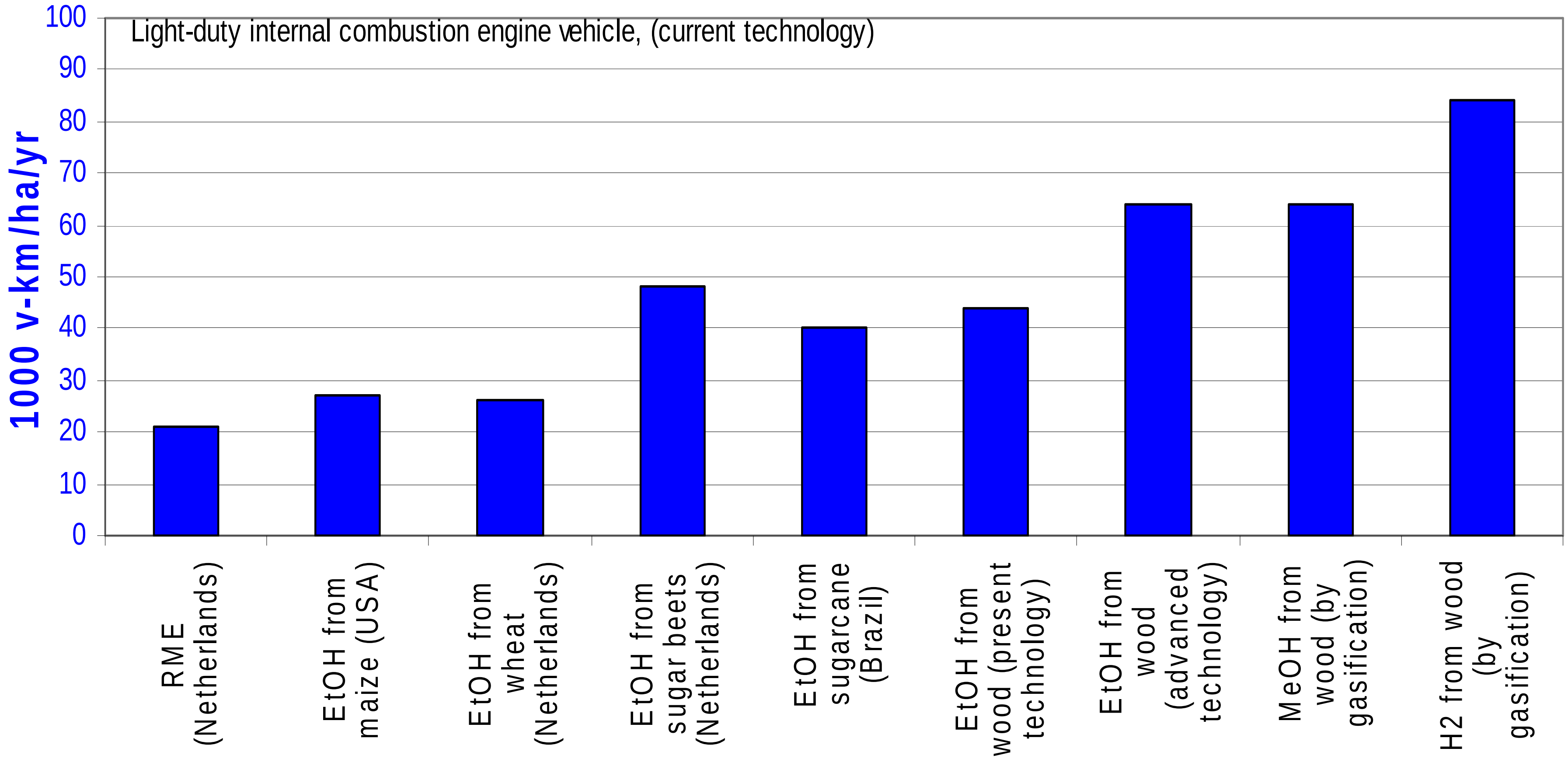
Mass Balance of Palm Oil Processing

OIL PALM: PPI-Yangambi: Recyclable Energy (1 kWh = 3.6 GJ)

Simulated data on yearly basis			PPI-YBI	PPI-YBI	12000ha	12000ha
(t) ou (GJ)	*Cornet et al.*				*4,1*	*7,0*
Huile de palme (t)	23,0	1,0	4,1	7,0	49680,0	84000,0
palm frond litter	**46,0**	**2,0**	**8,3**	**14,0**	**99360,0**	**168000,0**
trunk						
fruit bunch	100,0	4,3	18,0	30,4	216000,0	365217,4
empty fruit bunch	40,0	1,7	7,2	12,2	86400,0	146087,0
e.f.b. energy (GJ)	360,0	15,7	64,8	109,6	777600,0	1314782,6
empty fr.b. ash	**0,7**	**0,0**	**0,1**	**0,2**	**1512,0**	**2556,5**
mesocarp press fiber	16,0	0,7	2,9	4,9	34560,0	58434,8
m.p.f. energy (GJ)	88,0	3,8	15,8	26,8	190080,0	321391,3
kernel shell	10,0	0,4	1,8	3,0	21600,0	36521,7
k.s. energy (GJ)	144,0	6,3	25,9	43,8	311040,0	525913,0
endocarp kernel	5,0	0,2	0,9	1,5	10800,0	18260,9
kernel oil	*2,5*	*0,1*	0,5	0,8	5400,0	9130,4
kernel cake	2,5	0,1	0,5	0,8	5400,0	9130,4
mill effluent- Zaini Ujang et al. (2010)	**80,5**	**3,5**	**14,5**	**24,5**	**173880,0**	**294000,0**
POME Methane (Yacob)	1,0	0,0	0,2	0,3	2149,2	3633,8
P.M. Energy (GJ)	55,2	2,4	9,9	16,8	119278,2	201678,1
TOTAL Projected Output (GJ)	**647,2**	**28,1**	**116,5**	**197,0**	**1397998,2**	**2363765,1**
Input energy (GJ)	**11,5**	***4,0***	**16,6**	**28,0**	**198720,0**	**336000,0**

VIII. COMPETITIVE ADVANTAGE OF PERENNIAL CROPS

Grain biofuels give less energy services (and more GHG emissions) per ha/yr than lignocellulosic crops



IPCC, 1996.

Km is described as the concentration of the substrate to which the velocity of the reaction is half maximal

BAMBOO

BIOMASS COMPARISON

CRITERIA	CORN	BAMBOO (BAMBUSA EDULIS)
Affected by weather?	Yes	Not Really
Harvesting	1 time in a year	3 times in a year
Nutrients and fertilizers	Yes	No
Gallons of Ethanol per acre	300	800
Yield gallons per acre in a year	300	2400

*A bushel of corn used in the dry grind ethanol process yields 2.8 gallons of ethanol. Source: RFA Ethanol Industry Annual Outlook 2008

*The Corn Growers Association cites 300 gallons of ethanol production per acre as a standard.

*Each acre can yield 320 mounds of Bamusa Edulis and dry bamboo can produce 2.5 gallon per mound.

IX. COMBUSTION ENERGY FROM COPPICING LIGNIFIED BIOMASS = PRIME CHOICE

Charcoal and brikets from Bamboo

SALIX, POPULUS

Flächenerträge	**Einheit**	**Pappel Ertrag**	**Weide Ertrag**
-Ertrag auf 70% TM bezogen	T FM/ha	8.6-20.0	55-152
-Lagerverluste	%	20	20
-Energieertrag bei 70% TM	GJ/ha	83-194	55-152
	kWh/ha	23139-53991	15337-42177
-dito in Heizöläquivalent	l/ha	2314-5399	1534-4218

Quelle: Energiepflanzenproduktion
Über G. Reisinger

Table 4 Current electricity production costs from eucalyptus biomass (30 MW capacity producing 240 000 MWh per year)

Plant details	Unit	Estimate
Conversion rate	MWh per tonne of green feed	0.59259
Green feed required	million tonnes per year	0.405
Unit cost of green feedstock	$ per tonne	36
Costs		
Capital expenditure	$ million	42
Operating costs	$ million	14.1
Required product selling price ex factory[a]	$ per MWh	93.5

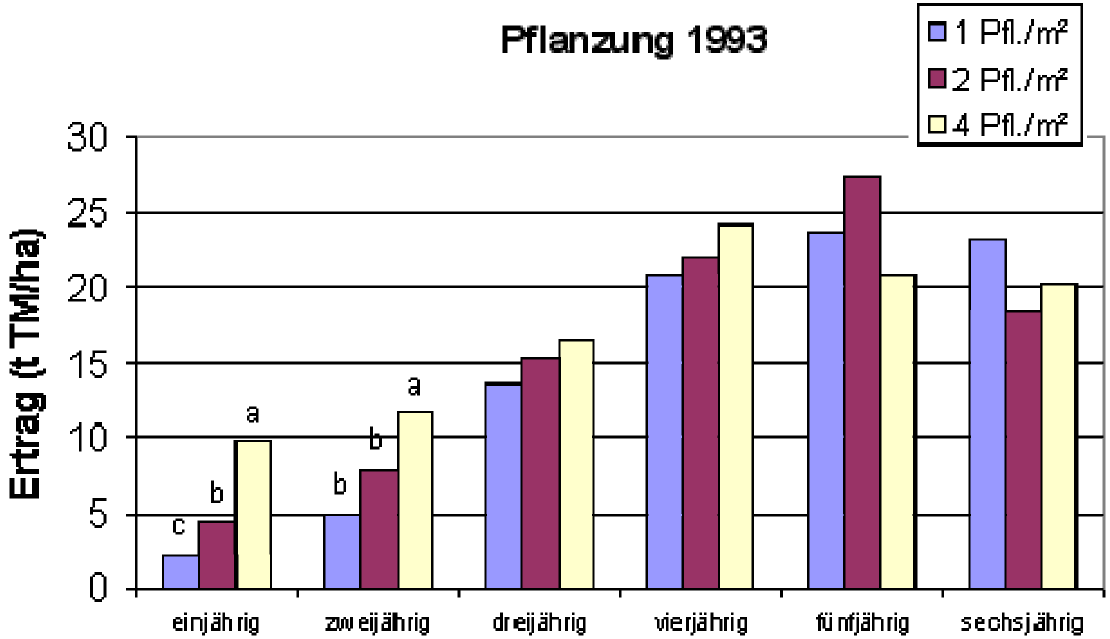
[a] To generate IRR on investment of 15 per cent over 15 years

Source: RIRDC (2002)

"High returns through responsible resource preservation and cultivation."

EUCALYPTUS

MISCANTHUS – Dikopshof
Campus Klein-Altendorf (Uni-Bonn)



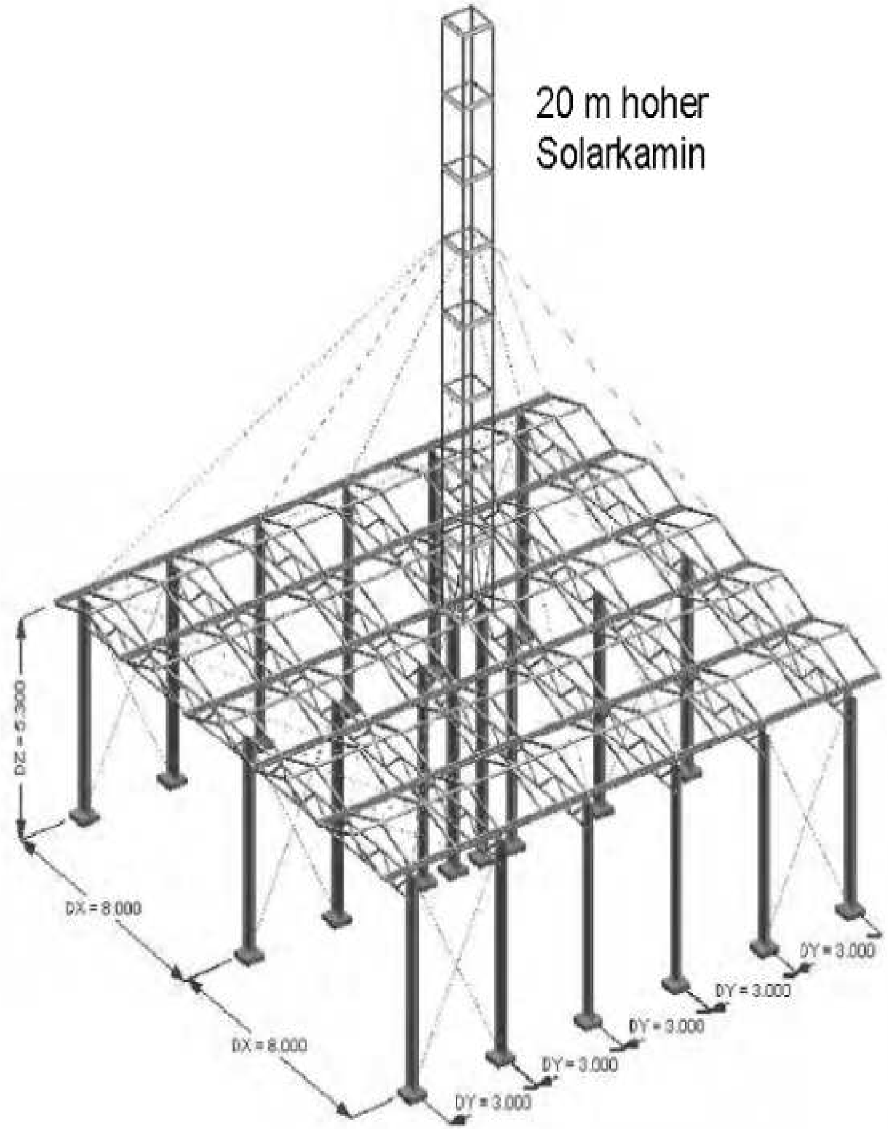
Innovative Erntetechnik:
„Tree-Eater", Schnittholzsammler

Energy Balance of Miscanthus and Rape Seed

Source: www.miscanthus.de

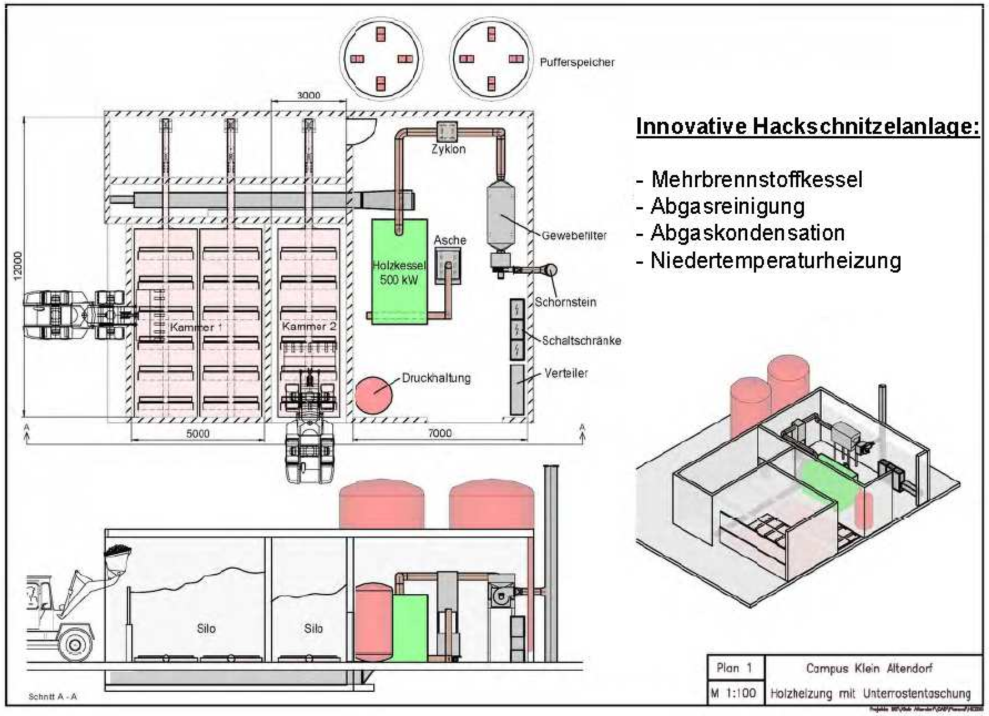
	Rape without straw (KWh/ha)	**Miscanthus 25t/ha KWh/ha**
Soil Management, Seed dressing, seed bed	416	27
Fertilizer	3394	1062
Plant protection	504	32
Harvesting	157	1950
Soil management	-	19
Transport	98	959
Drying (storage)	191	13000
Oil	1988	-
Input	**6748**	**17049**
Output	**12794**	**106250**
Input/Output	**1/1.9**	**1/6**

AgroHort-solar:
Biomasselager mit solarer Trocknung



ENERGIE-KONZEPT Campus Klein-Altendorf (Uni-Bonn et al.)

Energiekonzept Campus Klein-Altendorf
gefördert durch das LANUV, NRW



X. ENERGY PRODUCTION FROM BIOMASS - BIOENERGIEDORF JÜHNDE (KASSEL)

Wooden pellets

XI. TRADING OF CARBON CREDITS From 30$ down to 3$/u

Carbon credits currently (March 2013) traded at <3.5USD/u

1 unit of Carbon credit = 1 t CO_2 emitted

REDD+ at project scale: Evaluation and development guide

http://onfinternational.org/

Reforestation

Evolution of carbon credit market

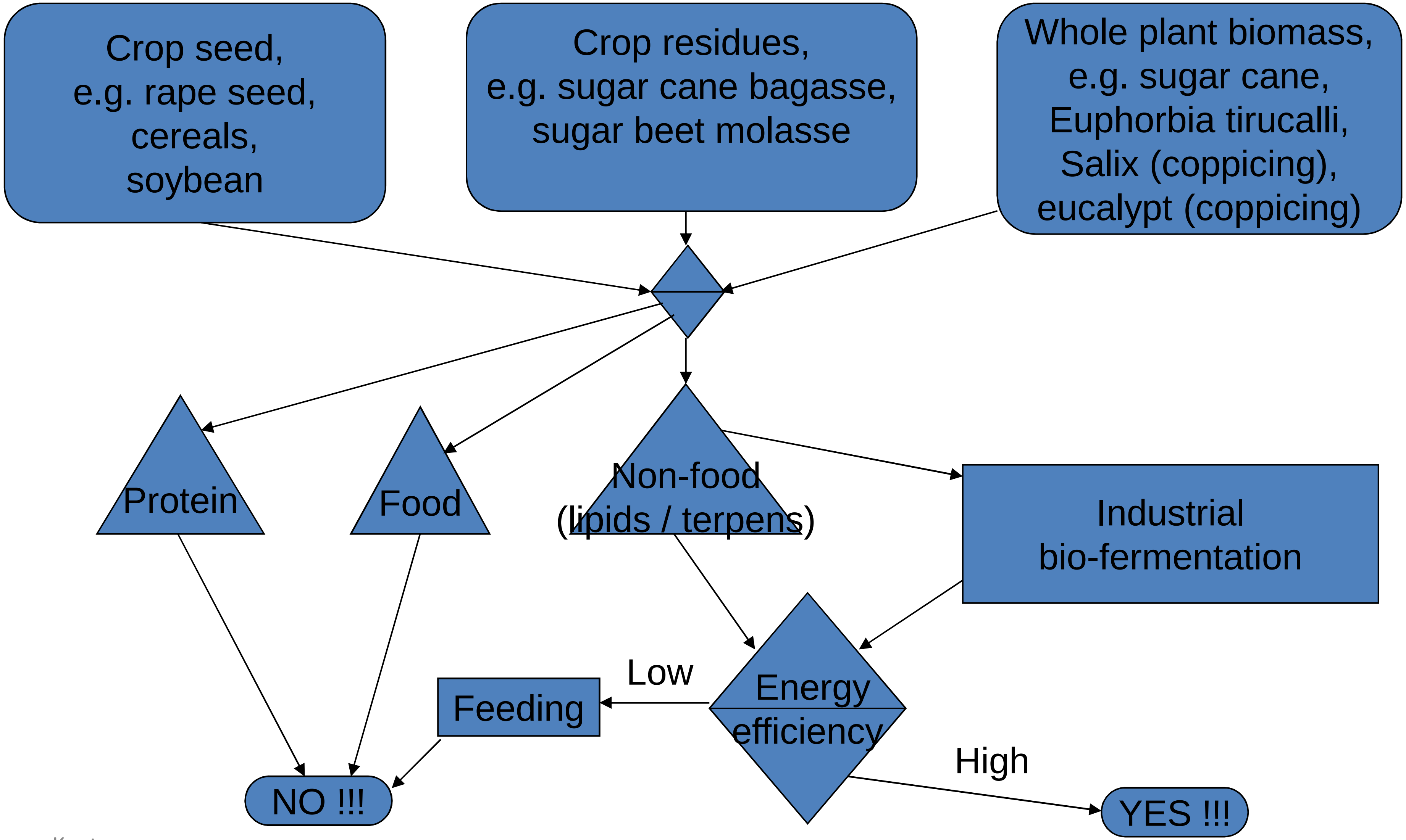
(in $US/carbon credit)

(One ton of dry wood is equivalent to 1.8 tons of CO_2
or 1 t CO_2 = 1/1.8 t biomass = 0.56 t biomass)

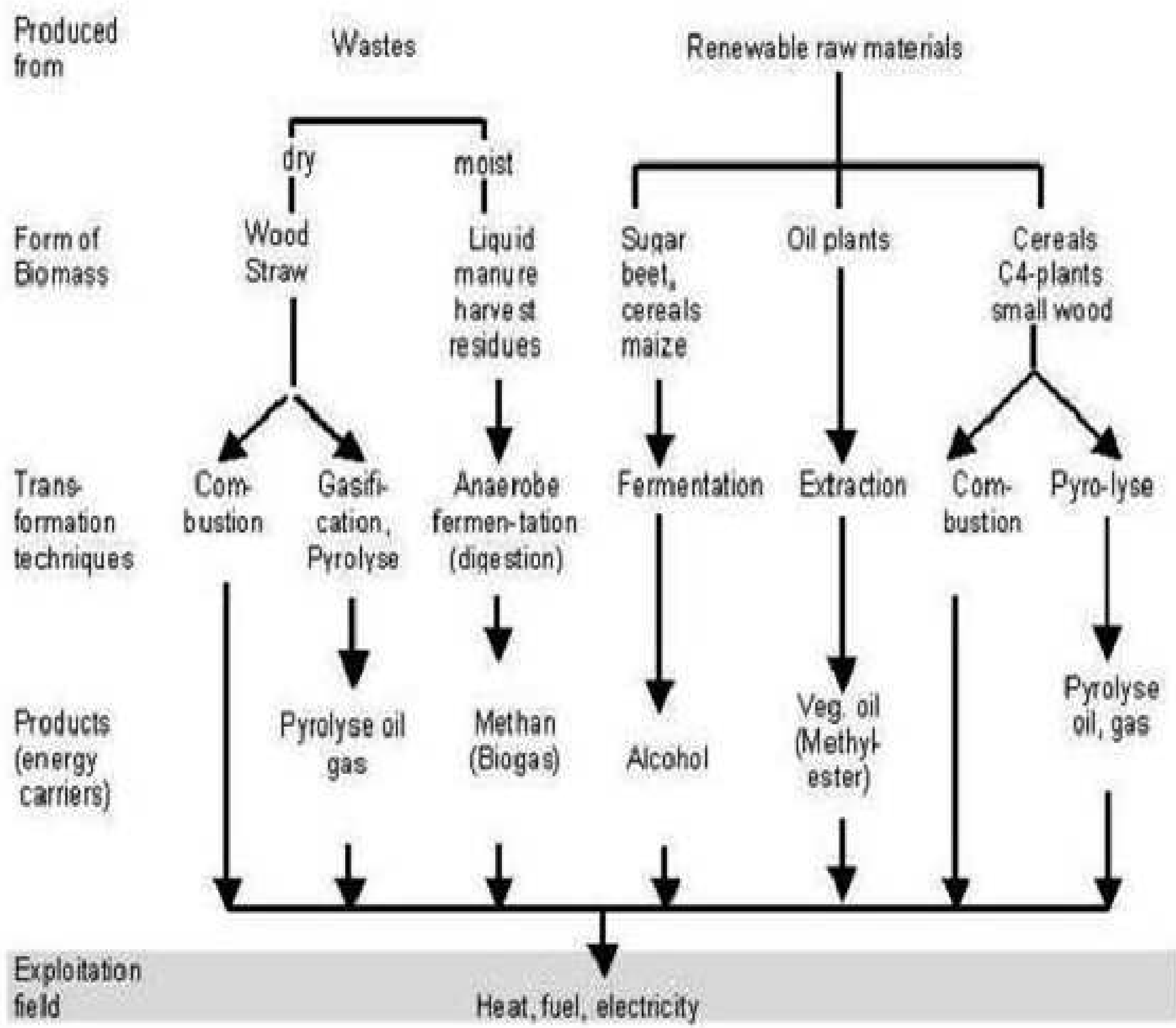
JA last 30 days

Source: EUA last 30 days
http://www.pointcarbon.com/productsandservices/carbon/

XII. Decision paths leading to bio-energy



WEITERE ENTSCHEIDUNGSWEGE



CONCLUSIONS

- I. AGRICULTURE IS ALTERNATE CONCENTRATION/DILUTION OF RESOURCES
- II. CROPS ARE NOT WEIGT-WATCHERS BUT SPACE INVADERS
- III. PLANTS MAXIMIZE ENERGY/M^2 BUT MINIMIZE ENERGY/M^3
- IV. BRAZILIAN SUGAR CANE AT THE FORE OF THE BIOETHANOL REVOLUTION
- V. ENERGY CONCENTRATION OF PLANT COMPONENTS
- VI. BIODIESEL THROUGH TRANSESTERIFICATION IS SELF-DEFEATING
- VII. COMPETITIVE ADVANTAGE OF OIL PALM
- VIII. COMPETITIVE ADVANTAGE OF PERENNIAL CROPS
- IX. COMBUSTION ENERGY FROM COPPICING LIGNIFIED BIOMASS = PRIME CHOICE
- X. ENERGY PRODUCTION FROM BIOMASS - BIOENERGIEDORF JÜHNDE (KASSEL)
- XI. TRADING OF CARBON CREDITS: From 30$ down to 3$/u
- XII. DECISION PATHS LEADING TO BIO-ENERGY
- XIII. GRETCHENFRAGE: WELCHE ENERGETISCHE VERWERTUNG FÜR WELCHEN PFLANZENART. WELCHEN PFLANZENCOMPONENT UND WELCHE ANWENDUNG???

SCHÖNEN DANK!

Energy content
(Wikipedia)

Fuel Type	Specific Energy Density (MJ/kg)
Solid Fuels	
Bagasse (Cane Stalks)	9.6
Chaff (Seed Casings)	14.6
Animal Dung/Manure	[1] 10-[2] 15
Dried plants $(C_6H_{10}O_5)_n$	10 – 16
Wood fuel $(C_6H_{10}O_5)_n$	16 – 21
Pyrolysis oil	17.5
Methanol (CH_3-OH)	19.9 – 22.7
Ethanol (CH_3-CH_2-OH)	23.4 – 26.8
Butanol(CH_3-$(CH_2)_3$-OH)	36
Fat	37.656
Biodiesel	37.8
Sunflower oil ($C_{18}H_{32}O_2$)	[4] 39.49
Castor oil ($C_{18}H_{34}O_3$)	[5] 39.5
Olive oil ($C_{18}H_{34}O_2$)	39.25 - 39.82
Methane (CH_4)	55 – 55.7
Hydrogen (H_2)	120 – 142
Coal	29.3 – 33.5
Crude Oil	41.868
Gasoline	45 – 48.3
Diesel	48.1
Natural Gas	38 – 50